FIBROUS FORMED PRODUCTS AND METHODS FOR MANUFACTURING SUCH FIBROUS FORMED PRODUCTS

[0000]

This application claims priority to Japanese patent application serial number 2003-142008, the contents of which are incorporated herein by reference.

[0001]

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to fibrous formed products that include a low-density layer coarsely formed mainly by thick fibers and interleaved between high-density layers that are closely formed mainly by thin fibers. The present invention also relates to methods of manufacturing such fibrous formed products.

[0002]

Description of the Related Art

Japanese Laid-Open Patent Publication No. 6-200460 teaches a known fibrous formed product and a method for manufacturing such a product. The known fibrous formed product of this publication is shown in FIG. 5 and is labeled with reference letter "A". The fibrous formed product "A" includes a low-density core layer 51, and upper and lower high-density surface layers, 53 and 55, disposed on the upper and lower surfaces of the core layer 51. The core layer 51 is coarsely formed mainly by thick inorganic fibers (15 μm in thickness). The surface layers 53 and 55 are closely formed mainly by thin inorganic fibers (10 μm in thickness).

[0003]

In order to manufacture the fibrous formed product "A", different machines separately form the core layer 51, the upper surface layer 53, and the lower surface layer 55. These layers are then overlaid with one another and are needle-punched to form a fibrous mat. Subsequently, the upper and lower sides of the fibrous mat are overlaid with resin films. The resin films are heated. Finally, a heat press machine presses the fibrous mat with the heated resin films, bonding the fibers of the mat to each other by the melted resin. Obtaining the fibrous formed product "A".

[0004]

However, the known method for manufacturing the fibrous formed product "A" requires several machines for separately forming the core layer 51 and the upper and lower surface layers, 53 and 55. This may increase the overall machine cost. In addition, because it is necessary to join the layers 51, 53, and 55, after they are overlaid with one another, the manufacturing efficiency is relatively low.

[0005]

SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to teach improved techniques that can reduce the machine cost for manufacturing fibrous formed products and that can increase the relative manufacturing efficiency of the fibrous formed products.

[0006]

According to one aspect of the present teachings, methods of manufacturing fibrous formed products are taught. The fibrous formed product includes a low-density layer, coarsely formed mainly by thick fibers, interleaved between upper and lower high-density layers, closely formed mainly by thin fibers. The methods may comprise the following steps (a) to (f):

(a) Preparing a mixture of fibers, including thick fibers and thin fibers. The average weight of a thin fiber is less than the average weight of a thick fiber.

(b) Forming first and second fibrous mats from the mixed fibers. Each of the first and second fibrous mats comprises a low-density layer, coarsely formed mainly of thick fibers, and a high-density layer, closely formed mainly of thin fibers. Each of the first and second fibrous mat is formed by the following sub-steps (b1) and (b2):

(b1) Supplying the mixed fibers onto the outer peripheral surface of a roller. The roller configured so as to temporarily retain the mixed fibers on the outer peripheral surface.

(b2) Rotating the roller so as to rotate the mixed fibers with the roller and releasing the mixed fibers from the roller, so that the mixed fibers are thrown toward a flat fiber-receiving surface due to the rotational force of the roller. The released fibers form a fibrous mat on the flat fiber-receiving surface.

(c) Inverting one of the first and second fibrous mats.

(d) Overlaying the first and second fibrous mats such that the low-density layers of each fibrous mat oppose each other.

(e) Joining the overlaid two fibrous mats to each other.

(f) Bonding the fibers together.

[0007]

According to these methods, the rotational force of the roller throws the mixed fibers from the outer peripheral surface of the roller, causing them to fall onto the flat fiber-receiving surface. Therefore, the thick fibers may reach the fiber-receiving surface before the thin fibers reach the fiber-receiving surface. Consequently, the low-density layer mainly comprising the thick fibers is formed first on the fiber receiving surface. Thereafter the high-density layer, mainly comprising the thin fibers, is formed on the low-density layer via an intermediate layer, referred to as a transition layer. As a result, a single process step may form a fibrous mat on a fiber-receiving surface, the mat having a low-density layer and a high-density layer.

[0008]

The first fibrous mat and the second fibrous mat may be obtained by the above step. One of the two mats is inverted. The two mats are then overlaid with each other such that the low-density layers directly oppose each other. The first fibrous mat and the second fibrous mats are thereafter joined to each other. The fibers of the two mats are bonded together, forming a composite fibrous formed material having upper and lower high-density layers, and a low-density layer interleaved between the high-density layers.

[0009]

According to these methods, a fibrous mat having a low-density layer and a high-density layer can be formed with a single process step. Therefore, the number of machines required for manufacturing a fibrous formed product can be reduced in comparison with the known methods that require separate machines for forming a low-density layer, an upper high-density layer, and a lower high-density layer. As a result, the overall machine cost can be reduced. In addition, because the fibrous mat can be formed by a single process step, the fibrous mat manufacturing efficiency may be improved.

[0010]

In another aspect of the present teachings, the same roller and the same fiber-receiving surface may be used to form the first and second fibrous mats.

[0011]

In another aspect of the present teachings, different rollers may be used to form the first and second fibrous mats. In such a case, the step (c) may comprise positioning the first fibrous

mat on a surface. The first fibrous mat is oriented such that the high-density layer contacts the surface and the low-density layer is exposed to the environment, for example, in an upward orientation away from the surface. The second fibrous mat is positioned such that the low-density layer of the second fibrous mat is directly opposite the low-density layer of the first fibrous mat. The second fibrous mat is placed upon the first fibrous mat.

[0012]

Therefore, the second fibrous mat may be directly placed on the first fibrous mat in order to form the fibrous formed product. Therefore, the efficiency of manufacturing the fibrous formed product can be further improved.

[0013]

In another aspect of the present teachings, the first and second fibrous mats are formed on different fiber-receiving surfaces. The step of inverting the first fibrous mat (step (c)) also comprises automatically inverting and transferring the first fibrous mat onto a moving surface located below the roller used for forming the second fibrous mat. The second fibrous mat is formed directly upon the inverted first fibrous mat. The low-density layers of each mat are adjacent to one another.

[0014]

In another aspect of the present teachings, the thin fibers comprise inorganic fibers and thermoplastic resin fibers. The thermoplastic resin fibers serve as agents for bonding the other fibers together. More specifically, the thermoplastic resin fibers may be melted by heat in order to bond the inorganic fibers together and/or to bond the inorganic fibers to the thick fibers.

[0015]

Preferably, the thermoplastic resin fibers comprise polypropylene fibers having a diameter selected between 15 μm and 17 μm.

[0016]

Preferably, the inorganic fibers comprise carbon fibers having a diameter less than 10μm.

[0017]

Preferably, the thick fibers comprise sisal hemp fibers having a diameter selected between 80 μm and 250 μm.

[0018]

In another aspect of the present teachings, fibrous formed products are taught that comprise a low-density layer coarsely formed mainly by thick fibers, and first and second high-density layers closely formed mainly by the thin fibers. The low-density layer is interleaved between the first and second high-density layers. The thick fibers have a diameter selected between 80 μm and 250 μm. Preferably, the thick fibers comprise sisal hemp fibers.

[0019]

Because the diameter of the thick fibers is equal to or larger than 80 μm, the necessary thickness and rigidity of the fibrous formed product can be ensured. However, because the diameter of the thick fibers is less than or equal to 250 μm, the low-density layer's ability to deform may not be degraded, maintaining the formability of the fibrous formed product.

[0020]

Preferably, the thin fibers comprise inorganic fibers and thermoplastic resin fibers. The thermoplastic resin fibers may serve as agents for bonding the other fibers together. For example, the thermoplastic resin fibers may be polypropylene fibers that have a diameter selected between 15 μm and 17 μm.

[0021]

Preferably, the inorganic fibers comprise carbon fibers that have a diameter of less than 10μm.

[0022]

In another aspect of the present teachings, fibrous mat manufacturing machines are taught that include a rotary roller having an outer peripheral surface and a fiber retaining device for retaining fibers on the outer peripheral surface within a predetermined angle of rotation. A supplier serves to supply a mixture of thick fibers and thin fibers onto the outer peripheral surface of the roller. A conveyor is disposed below the roller and is adapted to receive and convey the fibers that are thrown from the roller as the roller rotates. A fibrous mat is formed on the conveyor comprising a high-density layer formed mainly by the thin fibers and a low-density layer formed mainly by the thin fibers.

[0023]

Therefore, a fibrous mat having a high-density layer and a lower density layer can be manufactured by a single process step. As a result, the number of machines required for manufacturing the fibrous mat can be reduced. The one step process allows the manufacturing

costs to be reduced and the manufacturing efficiency to be improved. Therefore, the single machine can be advantageously used in manufacturing a fibrous formed product having a low-density layer interleaved between a first and second high-density layers.

[0024]

Preferably, the fiber-retaining device comprises a plurality of needles extending outward from the outer peripheral surface of the roller.

[0025]

The fiber-retaining device may further include auxiliary rollers that are disposed along the outer peripheral surface of the roller, and each of the rollers is spaced from the outer peripheral surface of the roller by a predetermined clearance.

[0026]

Preferably, the conveyor comprises a conveyor belt that is driven at a constant speed. The speed may be approximately proportional to the amount of material per length and/or the thickness of the resulting fibrous mat, for a given rotational speed of the roller.

[0027]

In another aspect of the present teachings, fibrous mat manufacturing machines are taught that may include a first and a second rotary roller. Each rotary roller has an outer peripheral surface. The outer peripheral surface has a device for retaining fibers on the outer peripheral surface within a predetermined angle of rotation. First and second suppliers respectively serve to provide a mixture of thick fibers and thin fibers onto the outer peripheral surfaces of the first roller and the second roller. A first conveyor is disposed below the first roller and serves to receive and convey the fibers. The fibers are thrown from the first roller as the first roller rotates, so that a first fibrous mat comprising a first high-density layer, formed mainly by the thin fibers, and a first low-density layer, formed mainly by the thick fibers, is formed on the first conveyor. A second conveyor is disposed below the first conveyor and the second roller. The second conveyor serves to receive and convey the first fibrous mat in an inverted position. The second conveyor also serves to receive the fibers that are thrown from the second roller as the second roller rotates, so that a second fibrous mat comprising a second high-density layer, formed mainly by the thin fibers, and a second low-density layer, formed mainly by the thick-fibers, is formed on top of the first fibrous mat. The second fibrous mat is

formed such that the first low-density layer of the first fibrous mat directly opposes the second low-density layer of the second fibrous mat.

[0028]

With this construction, the fibrous mat manufacturing machine can continuously manufacture a composite mat composed of the first and second fibrous mats. The composite mat has upper and lower, outer high-density layers, and an inner low-density layer interleaved between the outer high-density layers. Therefore, the composite mat can be readily used for example, in press forming manufacturing in order to produce a product having a desired configuration, such as a configuration suitable for the ceiling material of an automobile.

[0029]

Preferably, the fiber-retaining devices of the first and second rollers comprise a plurality of needles extending outward from the outer peripheral surface of the corresponding roller.

[0030]

Preferably, the fiber-retaining devices of the first and second rollers further include auxiliary rollers that are disposed along the outer peripheral surface of each of the corresponding rollers. Each of the auxiliary rollers is spaced apart from the outer peripheral surface of each of the corresponding rollers by a predetermined clearance.

[0031]

Preferably, each of the first and second conveyors comprises a belt conveyor that is driven at a relatively constant speed.

[0032]

Preferably, the first and second conveyors are driven in opposite directions to one another. Therefore, the first fibrous mat may be smoothly inverted when the first fibrous mat is transferred onto the second conveyor.

[0033]

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1(A) is a schematic side view of a first representative fibrous mat manufacturing machine showing a first representative method for manufacturing a fibrous mat that is adapted to be formed into a fibrous formed product; and

FIG. 1(B) is a schematic vertical sectional view of the fibrous mat about the section BB; and

FIGS. 2(A) and 2(B) are schematic vertical sectionals views showing an initial process for manufacturing the fibrous formed product by overlaying first and second fibrous mats with one another; and

FIGS. 3(A) to 3(C) are schematic views showing a subsequent process for manufacturing the fibrous formed product; and

FIG. 3(D) is a schematic view showing a process for forming the ceiling material for an automobile from the fibrous formed product; and

FIG. 4(A) is a schematic side view of a second representative fibrous mat manufacturing machine showing a second representative method for manufacturing a fibrous mat that is adapted to be formed into a fibrous formed product; and

FIGS. 4(B) and 4(C) are schematic vertical sectional views of a first fibrous mat, taken about the section BB, and a composite mat, taken about the section CC, formed by the second representative method; and

FIG. 5 is a schematic vertical sectional view of a known fibrous formed product.

[0034]

DETAILED DESCRIPTION OF THE INVENTION

Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved methods and machines for manufacturing fibrous formed products, and the fibrous formed products manufactured by such methods and machines. Representative examples of the present invention, which examples utilize many of these additional features and teachings both separately and in conjunction with one another, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

[0035]

(FIRST REPRESENTATIVE EMBODIMENT)

A first representative fibrous formed product and a first representative method of manufacturing such a fibrous formed product will now be described with reference to FIGS. 1 through 4. The first representative fibrous formed product is embodied as a panel that may be used as the base material of a ceiling member in an automobile. FIG. 1(A) shows a first representative machine 30 for manufacturing a fibrous mat. FIGS. 2(A) and 2(B) show steps of manufacturing a fibrous mat that becomes the material of a fibrous formed product. FIGS. 3(A) through 3(D) show the steps of manufacturing a ceiling member of an automobile.

[0036]

Referring to FIG. 2(B), a fibrous formed product 10 is made of two sheets of fibrous mats 20. Each of the fibrous mats 20 are formed by approximately 25% by weight of natural fibers, approximately 25% by weight of inorganic fibers, and approximately 50% by weight of thermoplastic fibers. The natural fibers preferably may be sisal hemp fibers having a thickness of about 150 to 160 μm and a length of about 150 mm. The average weight of the sisal hemp fibers may be approximately 0.082 g.

[0037]

Th inorganic fibers preferably may be carbon fibers having a thickness (diameter) of about 7 μm and a length of about 100 mm. The average weight of the carbon fibers may be approximately 0.0001 g.

[0038]

The thermoplastic fibers are incorporated for bonding the inorganic fibers to each other and for bonding the inorganic fibers to the natural fibers. Preferably, the thermoplastic fibers may be polypropylene fibers that have a thickness (diameter) of about 15 to 17 μm and have a length of about 64 mm. The average weight of the polypropylene fibers may be approximately 0.00002 g.

[0039]

As shown in FIGS. 1(B), 2(A), and 2(B), a high-density layer 22 is positioned on a top side (upper side) of each fibrous mat 20 and is closely formed mainly by the thin and light fibers, such as the carbon fibers and the thermoplastic fibers. A low-density layer 24 is positioned on the bottom side (lower side) of each fibrous mat 20 and is coarsely formed

mainly by the thick and heavy fibers, such as sisal hemp fibers. The high-density layer 22 and the low-density layer 24 are joined to each other via an intermediate layer 23. The intermediate layer 23 does not define a distinct boundary but has a density distribution varying between the layers 22 and 24. In general for this particular embodiment, the percentage of the carbon fibers and the thermoplastic fibers in the intermediate layer 23 increases in the direction toward the high-density layer 22. Conversely, the percentage of the sisal hemp fibers in the intermediate layer 23 increases in the direction toward the low-density layer 24.

[0040]

Two sheets of the fibrous mats 20 are used to form the fibrous formed product 10. The two sheets of fibrous mats 20 are overlaid with each other such that the low-density layer 24 of one fibrous mat 20 directly opposes the low-density layer 24 of the other fibrous mat 20 (as seen in FIGS. 2(A) and 2(B)). The fibrous mats 20 are then needle-punched by a needle punching machine (not shown). The average surface density (mass per unit area) of the fibrous mats 20 in the overlaid state is preferably chosen to be approximately in the range of 450 g/m^2 to 600 g/m^2.

[0041]

The machine 30 for manufacturing the fibrous mats 20 will now be described. The steps of manufacturing the fibrous formed product 10, formed of the fibrous mats 20, and the steps of manufacturing a ceiling material, will be described after the machine 30 has been described. The ceiling material may be used for an automobile and may be formed from the fibrous formed product 10.

[0042]

As shown in FIG. 1(A), the machine 30 for manufacturing the fibrous mats 20 includes a main roller 32 that is rotatably driven while the sisal hemp fibers, carbon fibers, and thermoplastic fibers (hereinafter generally called "fibers F") are temporarily carried or caught on an outer peripheral surface 34 of the main roller 32. To this end, the main roller 32 has a horizontal rotational axis and a plurality of needles 36 that extend outward from the outer peripheral surface 34 for carrying the fibers F.

[0043]

A plurality of auxiliary rollers 38 is disposed about the main roller 32 and is arranged along a circumferential direction of the main roller 32 along the outer peripheral surface 34.

The auxiliary rollers 38 serve to help hold the fibers F carried on the outer peripheral surface 34 of the main roller 32. The auxiliary rollers 38 have rotational axes that are parallel to the rotational axis of the main roller 32. An outer peripheral surface 38r of each auxiliary roller 38 is spaced apart from the outer peripheral surface 34 of the main roller 32 by a predetermined distance. In addition, the auxiliary rollers 38 are rotatably driven in a direction opposite to the rotational direction of the roller 32, so that the fibers F carried on the outer peripheral surface 34 of the main roller 32 can smoothly pass through the spaces between the peripheral surface 34 and the auxiliary rollers 38.

[0044]

As indicated by an arrow in FIG. 1(A), the main roller 32 rotates in a counterclockwise direction and applies a rotational force (the rotational force includes the centrifugal force and the inertial force of the fibers F) to the fibers F. A fiber supplier 35 is disposed to the right and upper side of the main roller 32. The supplier 35 includes a storage tank 35h and a supply device 35f. The storage tank 35h serves to store a substantially homogeneous mixture of the sisal hemp fibers, carbon fibers, and thermoplastic fibers. The supply device 35f serves to supply the stored fibers F onto the outer peripheral surface 34 of the main roller 32 at a predetermined volume per unit of time.

[0045]

A fiber conveyor 31 is configured as a conveyor belt and is horizontally disposed below the main roller 32. The fiber conveyor 31 is driven so as to correspond to the rotation of the main roller 32. The fiber conveyor 31 serves to receive the fibers F that have been thrown downward from the outer peripheral surface 34 of the main roller 32 by the rotational force of the main roller 32 (among other forces). The fiber conveyor 31 is driven in a forward direction (right direction as viewed in FIG. 1(A)) at a relatively constant speed. The result is that the fibers F may be piled up onto the fiber conveyor 31. The fibers F form a fiber layer with a substantially uniform thickness. The driving speed of the conveyor 31 may be altered in order to adjust the thickness of the fiber layer.

[0046]

The step of manufacturing the fibrous mat 20 and the step of manufacturing the fibrous formed product 10 from two fibrous mats 20 will be hereinafter be described in connection with the operation of the machine 30.

[0047]

The main roller 32 is rotatably driven in a counterclockwise direction. The auxiliary rollers 38 are rotatably driven in a clockwise direction. The fiber conveyor 31 is driven so as to correspond to the rotation of the main roller 32. Once the main roller 32, the auxiliary rollers 38, and the conveyor 31, are all driven at their respective predetermined speeds, the fiber supplier 35 supplies fibers F onto the outer peripheral surface 34 of the main roller 32 at a predetermined volume per unit of time.

[0048]

The fibers F, supplied onto the outer peripheral surface 34 of the main roller 32, are engaged and retained by the needles 36 and rotate substantially together with the main roller 32. Auxiliary rollers 38, disposed about and adjacent the outer surface 34 of the main roller 32, may hold the fibers F near the outer peripheral surface 34 of the main roller 32. Therefore, the fibers F may be inhibited from being thrown out of connection with the main roller 32 by centrifugal force. When the fibers F, carried on the outer peripheral surface 34 of the main roller 32, reach the lower side of the main roller 32, free of further auxiliary rollers 38, the fibers F may be thrown downward towards the fiber conveyor 31 by the rotational force (e.g., centrifugal force and the inertia force) of the main roller 32.

[0049]

As described previously, thick and heavy fibers (e.g. sisal hemp) and the relatively thin and light fibers (e.g. carbon fibers and polypropylene fibers) are mixed to form fibers F. The rotational force of the main roller 32 acting upon the fibers F may allow the thick and heavy sisal hemp fibers to be thrown from the main roller 32 earlier and therefore reach the fiber conveyor 31 prior to the thin and light fibers, i.e. the carbon fibers and polypropylene fibers.

[0050]

The result, as shown in FIG. 1(B), is that a coarse or low-density layer 24, mainly comprising the thick and heavy sisal hemp fibers, may be first formed on the conveyor 31. The close or high-density layer 22, mainly comprising the thin and light carbon fibers and polypropylene fibers, may be formed on top of the low-density layer 24. The transitional intermediate layer 23 is established at the boundary of the low-density and high-density layers. The fibrous mat 20, having a predetermined thickness, may be formed on the conveyor 31 with the low-density layer 24 positioned on the lower side (as seen in FIG. 1 (B)). Preferably, the

speed of the conveyor 31 may be adjusted so that the fibrous mats 20 have an average surface density (mass per unit area) of approximately 450 g/m^2 to 600 g/m^2.

[0051]

Two sheets of fibrous mats 20, manufactured by the machine 30 according to the above steps, are then overlaid with each other such that the low-density layer 24 of one of the fibrous mats 20 directly opposes the low-density layer 24 of the other of the fibrous mats 20, as shown in FIGS. 2(A) and 2(B). The overlaid fibrous mats 20 are then needle punched by a needle punching machine (not shown), so that the fibrous mats 20 are joined to each other.

[0052]

Thereafter, the punched fibrous mats 20 are heated to the melting temperature of the polypropylene fibers. As shown in FIG. 3(A), surface skin materials 26 are laid over the upper and lower surfaces of the bonded fibrous mats 20 through the intervention of adhesive films (not shown). A hot press machine 43 presses the bonded fibrous mats 20 along with the surface skin materials 26, as shown in FIGS. 3(A) and 3(B). As a result, the melted polypropylene fibers may be impregnated throughout the carbon fibers of the high-density layer 22 and also throughout the sisal hemp fibers of the low-density layer 24. The carbon fibers are bonded to each other and are also bonded to the sisal hemp fibers. In addition, the surface skin materials 26 may be bonded to the corresponding high-density layers 22 of the bonded fibrous mats 20 via the melted polypropylene fibers and the adhesive films.

[0053]

The pressure of the hot press machine 43 is then released as shown in FIG. 3(C). The bonded fibrous mats 20 with the surface skin materials 26 bonded thereto are held in a released condition for a predetermined time period in order to obtain the fibrous formed product 10. During this time period, the thickness of the bonded fibrous mats 20 may recover to some extent due to the restoration forces produced by the low-density layer 24. After the predetermined time period, the final steps for manufacturing the fibrous formed product 10 may be completed.

[0054]

The fibrous formed product 10 may be transferred to a cold press machine 45 for final shaping, as shown in FIG. 3 (D). In this representative embodiment, the fibrous formed product 10 is cold pressed to have a configuration for use as ceiling material of an automobile.

[0055]

The ceiling material manufactured from the fibrous formed product 10 preferably has an average surface density (mass per unit area) of about 450 g/m^2 to 600 g/m^2. This representative embodiment may have a thickness of approximately 3.5 to 4.5 mm. This thickness is greater than the typical thickness (e.g. about 3 mm) of a conventional fibrous formed product that may have the same average surface density as the fibrous formed product 10. However, the conventional fibrous formed product has a uniform density throughout its thickness whereas the fibrous formed product 10 has layers of different densities.

[0056]

According to the representative method of manufacturing the fibrous formed product 10, the fibrous mat 20, including the low-density layer 24, intermediate layer 23, and the high-density layer 22, can be manufactured through the use of a simple process and a single machine 30. Overlaying two fibrous mats 20 such that their low-density layers 24 oppose each other assembles the fibrous formed product 10. The number of machines of the representative method may be reduced, saving the associated machine and other costs, in comparison with a conventional method, where separate machines typically manufacture a core low-density layer, an upper high-density layer, and a lower high-density layer. In addition, because the fibrous mat 20, comprising a low-density layer 24, intermediate layer 23, and a high-density layer 22, is manufactured during a single process, there is an improvement in the manufacturing efficiency of the fibrous formed product 10 as compared to a typical conventional method.

[0057]

In addition, because sisal hemp fibers having a thickness (diameter) greater than or equal to 150 μm are used as the main material of the low-density layer 24, the low-density layer 24 can provide the necessary thickness and the rigidity of the fibrous formed product 10. In addition, because the diameter of the chosen sisal hemp fibers is less than or equal to 160 μm, the low-density layer 24 may be relatively easily deformed, allowing the fibrous formed product 10 to be relatively formable. However, the necessary thickness and the rigidity of the fibrous formed product 10 can still be maintained to some degree if the diameter of the sisal hemp fibers is greater than or equal to 80 μm. In addition, the fibrous formed product 10 may still be formable to a certain extent if the diameter of the sisal hemp fibers is chosen to be less than or equal to 250 μm.

[0058]

Further, because the representative fibrous formed product 10 has a low-density layer 24 formed mainly by thick fibers, the fibrous formed product 10 may have a larger thickness than a conventional fibrous formed product with the same average surface density but with a uniform density throughout its thickness. Therefore, the clearance between the molds of the cold press machine 45 must be increased so that automobile ceiling material, comprised of the representative fibrous formed product 10 and formed by the cold press machine 45, may obtain a relatively larger thickness.

[0059]

Furthermore, because the thickness of the automobile ceiling material can be increased without affecting the average surface density, the rigidity of the automobile ceiling material can be increased and the acoustic absorption property of the ceiling material can be improved.

[0060]

(SECOND REPRESENTATIVE EMBODIMENT)

FIG. 4(A) is a schematic view of a second representative fibrous mat manufacturing machine 1 that can continuously form two fibrous mats 20 so that they are automatically overlaid in the correct orientations with one another.

[0061]

The machine 1 includes a first machine section 30a, for manufacturing one of the two fibrous mats 20 (hereinafter called "first fibrous mat 20") and a second machine section 30b, for manufacturing the other of the two fibrous mats (hereinafter called "second fibrous mat 20"). The basic construction of the first machine section 30a and the construction of the second machine section 30b are substantially the same as with the first representative machine 30, described previously. Therefore, in FIG. 4(A), the parts of the first and second machine sections that are the same as parts of the first representative machine 30 are labeled with the same reference numerals. A repeated description of these parts will not be necessary.

[0062]

The first machine section 30a is different from the first representative machine 30 in that the roller 32 of the first machine section 30a is rotatably driven in the clockwise direction in order to apply a rotational force to the fibers F1. As a result, the supplier 35 of the first machine section 30a is positioned to the left and to the upper side of the roller 32.

[0063]

The conveyor 31 is replaced with a first fiber conveyor 31a (hereinafter also called "first conveyor 31a") and a second fiber conveyor 31b (hereinafter also called "second conveyor 31b") that are configured as horizontal conveyor belts. The first and second conveyors 31a and 31b are driven at their respectively predetermined relatively constant speeds.

[0064]

The first conveyor 30a is disposed below the roller 32 of the first machine section 30a. Fibers F1 thrown down from the first machine section's roller 32 may be received by the first conveyor 31a so as to form a first fibrous mat 20. The first conveyor 31a is driven to convey the first fibrous mat 20 in a rearward direction (the leftward direction as viewed in FIG. 4(A)).

[0065]

The second machine section 30b is positioned forwardly (rightward as viewed in FIG. 4(A)) of the first machine section 30a and has a main roller 32 driven in the counterclockwise direction, applying a rotational force to the fibers.

[0066]

The second conveyor 30b is positioned below the first conveyor 30a and the roller 32 of the second machine section 30b. The second conveyor 30b may receive the first fibrous mat 20, transferred in an inverted orientation from the first conveyor 32a. In addition the second conveyor 30b may receive fibers F2 that are thrown downward from the main roller 32 of the second machine section 30b. These fibers F2 form the second fibrous mat 20. The second fibrous mat 20 is formed on top of the first fibrous mat 20. The second conveyor 30b conveys the combined first and second fibrous mats 20 in the forward direction (to the right as viewed in FIG. 4(A)).

[0067]

In operation, the fibers F1 thrown downward from the main roller 32 of the first machine section 30a and are received by the first conveyor 31a as described previously. Therefore, the first fibrous mat 20 may be formed on the first conveyor 31a with the low-density layer 24 positioned on the lower side. The first fibrous mat 20 may then be conveyed rearward (to the left as viewed in FIG. 4(A)). At the rear (left) end of the first conveyor 31a, the first fibrous mat 20 may be transferred onto the second conveyor 31b. Due in part to the conveying direction of the second conveyor 31b being opposite to the conveying direction of

the first conveyor 31a, the first fibrous mat 20 may be inverted upside down when it is transferred to the second conveyor 30b.

[0068]

In other words, the first fibrous mat 20 may be transferred onto the second conveyor 31b with the high-density layer 22 positioned on the lower side. This inverted first fibrous mat 20 is then conveyed forward (to the right as viewed in FIG. 4(A)) by the second conveyor 31b. The first fibrous mat 20 passes below the second machine section 30b at a relatively constant speed. The fibers F2 thrown downwardly from the main roller 32 of the second machine section 30b and are deposited onto the first fibrous mat 20 so as to have a substantially uniform thickness. Therefore, the second fibrous mat 20 is laid directly over the first fibrous mat 20 with the low-density layer 24 of the second fibrous mat 20 opposing the low-density layer 24 of the first fibrous mat 20.

[0069]

The first and second fibrous mats 20 overlaid with each other at the low-density layers 24 are then transferred to a needle punching machine (not shown) in order to be needle punched joined. The steps, necessary to manufacture the fibrous formed product 10, following the needle punching operation are the same as in the first representative embodiment.

[0070]

In this way, according to the second representative embodiment, the first and second fibrous mats 20 are continuously manufactured and automatically overlaid with one another. The resulting manufacturing efficiency of fibrous formed product 10 may be further improved.

[0071]

The present invention may not be limited to the above representative embodiments but may be modified in various ways. Although sisal hemp fibers are used as natural fibers forming the low-density layer 24 in the above representative embodiments, any other natural fibers, such as kenaf and palm fibers, among others, may be used in place of the sisal hemp fibers.

[0072]

In addition, although carbon fibers are used as inorganic fibers that form the high density layer 22, glass fibers and metal fibers, among others, may be used in place of carbon fibers.

[0073]

Further, although polypropylene fibers are used as thermoplastic fibers, olefin resin fibers, such as polyethylene and polybutene fibers, among others, may be used in place of polypropylene fibers.